

## Multilevel comparison of large urban systems

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For the first time the systems of cities in seven countries or regions among the largest in the world (China, India, Brazil, Europe, the Former Soviet Union (FSU), the United States and South Africa) are made comparable through the building of spatio-temporal standardised statistical databases. We first explain the concept of a generic evolutionary urban unit ("city") and its necessary adaptations to the information provided by each national statistical system. Second, the hierarchical structure and the urban growth process are compared at macro-scale for the seven countries with reference to Zipf's and Gibrat's model: in agreement with an evolutionary theory of urban systems, large similarities shape the hierarchical structure and growth processes in BRICS countries as well as in Europe and United States, despite their positions at different stages in the urban transition that explain some structural peculiarities. Third, the individual trajectories of some 10,000 cities are mapped at micro-scale following a cluster analysis of their evolution over the last fifty years. A few common principles extracted from the evolutionary theory of urban systems can explain the diversity of these trajectories, including a specific pattern in their geographical repartition in the Chinese case. We conclude that the observations at macro-level when summarized as stylised facts can help in designing simulation models of urban systems whereas the urban trajectories identified at micro-level are consistent enough for constituting the basis of plausible future population projections.

Urban theories and models are too rarely tested on sets of data that are properly defined and standardized. Many contradictory results and some controversial papers in urban studies can be explained by a lack of attention paid to the quality and quantity of empirical data. We think of crucial importance to establish solid and replicable results from sound data that are made comparable by using a common theoretical background for defining and delineating cities, whatever the heterogeneity of the published statistical information. We take here the opportunity of several coordinated PhD works[32] for comparing urban systems in seven among the largest countries in the world: China, India, Brazil, Europe, the Former Soviet Union (FSU), the United States and South Africa. This sample includes all the so-called BRICS countries that were for a while the most rapidly growing countries and illustrate urban systems in almost all continents at different stages of the urbanization process.

### Standardized databases for comparing urban systems according to an evolutionary concept of cities

Harmonised databases derived from an evolving concept of the city are a prerequisite for comparative urban studies. In our perspective of spatio-temporal compar-

isons, we define a city as a place in which the daily activities of most residents are concentrated. Its delineation constitutes a spatial "envelope" that evolves through time, generally in expansion. For each time period, we select an urban delineation that is suited to the local regime of socio-spatial interaction: thus, before the 19th century, administrative units (communes, municipios, or places) are sufficient to define "cities without suburbs" (see [1], p.291) that represent a dense body of population having requested and/or having been granted legal recognition by the political power. The form taken on by this recognition and the conditions depend on the political and institutional setting (for instance, request to be incorporated into the United States, or demographic threshold in Europe, or political decision as observed more recently in the USSR or China). With the industrial revolution, the city became a dense human group extending outside administrative boundaries, and it then requires a morphological definition (i.e. urban agglomeration) so as to reflect this continuity of built-up area. More recently, interactions linked to the use of car transport and long-distance commuting by people living in peri-urban settings but still working in the city centres led on to a functional description of the city (i.e. functional urban area) [6].

The present development of urban databases for the seven study zones is based on common principles, while at the same time allowing for adaptation to local constraints and political and administrative contexts[33]. Wherever possible, we have used population numbers derived from the finest possible administrative level (the basic units in the databases) and we performed aggregations of these elementary entities in order to follow the evolution of the urban object in the seven selected countries over long

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time spans (see Figure 1).

Table I sums up the final content of these databases and the method used to adapt our generic definition to the information available in each country. Few of these countries provide data based on a functional definition of the urban object, and the information is available only for certain dates (USA, Brazil). The database for Europe, which covers a longer historical time span, groups entities according to a morphological definition. Certain countries only give information at administrative level, fortunately in fairly wide units that are able to evolve (Russia: [9]). Different aggregation methods have been implemented to harmonise these databases: morphological aggregation on the basis of aerial photographs or satellite images (Europe, India, FSU); for South Africa, since the morphological definition lacks relevance in the case of the Apartheid city, entities that were functionally linked to the city, such as the black townships, were integrated [29]; the database for the USA uses an evolving definition of the city, considering legal entities alone until the change to urban agglomerations in 1870 and finally metropolitan areas (which are functional areas) from 1940 [5]; For China, the principle of urban agglomeration was applied, adjusting delineations of built-up areas collected on satellite images on the administrative grid of the qu, shi and xian [27].

The urban entities included in table 1 are those with more than 10,000 inhabitants at the date indicated. At the start of the 21st century, the numbers can vary from a few hundred to several thousands according to the country, but they remain fairly closely linked to the total urban population of the country, as shown in Figure 2, where a simple linear regression adequately fits three quarters of the variations of these two values. Each figure is foreseeable if the other is known, which means that the degree of concentration of the urban population varies little in the present-day world (a very approximate measure of the present degree of concentration in these large countries can be obtained by calculating an average size per city, about 100,000 inhabitants, which has of course no real geographical meaning) and this reflects a certain coherence in urbanisation processes overall, whatever the country considered. The United States appear as an exception, with far less urban units than expected from their total urban population. That huge concentration of the urban system can be explained by the historical process of settlement in the “New world” as well as by the very large size of the elementary spatial units aggregated in SMA’s (the counties). Even if we had included in the database the urban agglomerations instead of the SMA’s, the exception would remain, since there are 1380 “urbanized areas and urban clusters” over 10 000 inhabitants for a total of 237 million urban population (US Census Bureau, 2014)[34].

## Forms of urban hierarchy and growth processes

There is a vast corpus of literature about the forms taken on by urban hierarchies, and in particular the descriptions that refer to Zipf’s rank-size rule. Recent syntheses [20, 26] have not reached a consensus on the universal nature of this rule, nor on the factors that might explain its wide applicability, or the main reasons for the variations that are observed.

A first obstacle to the construction of scientific knowledge on this issue is the extreme heterogeneity of the samples of cities that have been used to perform the tests, and sometimes the doubtful quality of the definitions and delineations used to measure city size. We do not claim here to provide a final solution to this problem, but we do bring more credible results by using databases that are as comparable as possible, applying this to a large number of cities over fairly long time spans and for a variety of large countries of the world.

Another question is that of the definition of the city systems observed. Most often, Zipf’s law is tested on a set of cities in a single country. We are aware that this use of the nation-state framework (or a quasi continental framework in the case of Europe, US, China, India and the former Soviet Union) is probably no longer completely suited to the delineation of city systems, since the globalisation of exchanges brings cities to new interactions, the intensity and range of which vary according to city size. Nevertheless, urban hierarchical patterns, precisely because of the growth processes resulting from their interaction patterns, tend to be sustained over periods of several decades or even several centuries, and we think that the hierarchies observed here have been engaged in strong interactions for sufficiently long time for the patterns to continue to show up, even if the state borders enclosing them are no longer as impermeable as they were earlier.

## Macro-level analysis of urban hierarchies explained by territorial history

Our main results widely confirm the results reported by Moriconi-Ebrard [18] who used the Geopolis database to compare states across the world. They also go against the idea of a historical convergence towards a regular Zipf model with a slope of -1 as suggested in a recent article by Berry and Okulicz-Kozaryn [4].

Indeed, slope values for rank-size adjusted on these distributions vary, clearly differentiating countries and continents according to how long-standing their settlement is. The value of the rank-size slope is an index of size inequalities of cities. The variations of this index of urban size amplitude in a given territory can be fairly well explained by differences in the speed of transport systems enabling exchanges among cities, at the time when the urban networks become established: the lowest values (absolute value, i.e. without sign) are observed in

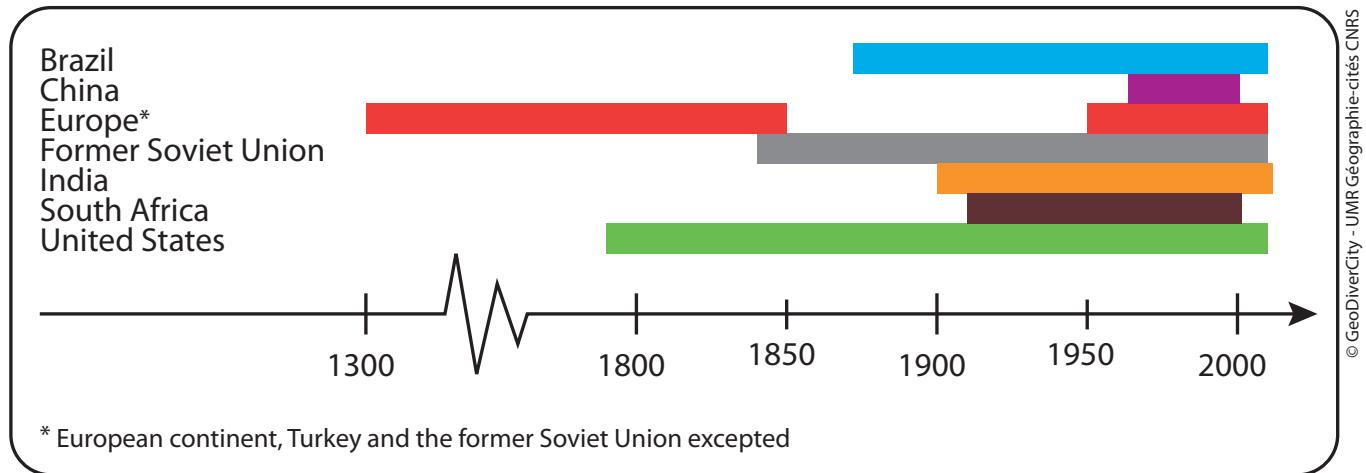


FIG. 1: Historical range of the urban data bases.

Database	$N_0$ (initial date)	$N_F$ (final date)	$D$	Method
Brazil (a)	531 (1872)	2615 (2010)	11	Administrative (municípios + metropolitan areas)
Former Soviet Union (DARIUS) (b)	91 (1840)	1929 (2010)	11	Morphological (municipalities at three administrative levels)
India (IndiaCities) (c)	503 (1901)	5841 (2011)	12	Combined morphological, and functional
China (ChinaCities) (d)	605 (1964)	9294 (2000)	4	Combined administrative (xian, qu, xianjishi (district level) and zhen, xiang (subdistrict level)) morphological and functional
South Africa (DYSTURB) (e)	14 (1911)	220 (2001)	10	Combined morphological and functional (white cities + black townships)
Europe (PARIS-Bairoch-Geopolis) (f)	3619 (1950)	4413 (2010)	14	Morphological (municipalities then agglomerations)
United States (Harmonie-cités) (g)	5 (1790)	909 (2010)	23	Combined administrative then morphological and functional (places, cities, retropolated micropolitan and metropolitan areas)

TABLE I: Harmonised urban databases for international comparisons (urban units > 10,000 inhab.).  $N_0$  : number of cities at (initial date) ;  $N_F$  : Number of cities at (final date) ;  $D$  : number of dates considered in the database. Sources : (a) IBGE, Instituto Brasileiro de Geografia e Estatística. Statistical tables for the Brazilian Empire and the Federal Republic of Brazil ; (b) Statistical tables for the Russian Empire, Russian Empire censuses, USSR censuses (archives), National censuses ; (c) Census of India ; (d) China Data Center and Chinese National Census Bureau ; (e) Statistics South Africa, South African institute of Race relations, Urban foundation, Census Statistics SA, DYSTURB (see [15]) ; (f) [1, 19] ; (g) USA census data: Census of Population and Housing.

countries that have been populated for a long time (India, China, Europe) and the highest values for countries that were settled more recently, higher transportation speed enabling a wider spacing between settlements as well as larger urban concentrations emerging on sparser spatial distributions of rural population (South Africa, the United States). The fairly high values for the Soviet Union could be explained by its relatively late industrialisation compared to Europe, and a more recent urban development of its Eastern areas in the Asiatic part, while Brazil escapes the general pattern with a moderate degree of urban concentration (see Table II).

The qualitative variations in shape of the size distribution are explained above all by the diversity of

the politico-administrative organisation of the territories concerned (see Figure 3). In countries that have been run under socialist regimes aiming at restraining urban growth, there is a levelling-off of the curves (in the FSU around one million inhabitants, in China around 100 000 inhabitants, corresponding to city sizes for which targeted investments have been made [8, 18]. Conversely the countries with the most marked macrocephaly (South Africa, India, Brazil) are those that have allowed their metropolises the greatest latitude.

Compared to the United States and Europe, the BRICS countries stand out for the particular shape of the upper part of their urban hierarchies: Russia is the only BRICS country to present a case of urban primacy, where

Country	$N$	$a$	$P_1/P_2$	$M$	$P_{tot} (\times 10^6)$
Brazil	2615	0.88	2	2	161
FSU	1929	1.10	3	0	173.5
India	5121	0.95	1.1	3	427
China	9294	0.80	1.3	0	481
South Africa	220	1.15	2	4	25
Europe	4413	0.96	1.2	2	291
United States	909	1.23	1.5	0	287

TABLE II: Comparing urban hierarchies: city size distributions around 2010. We consider the urban agglomerations larger than 10000 inhabitants. Rank size slope  $a$  is estimated from equation  $\log(P) = K - a \log(R)$  with  $P$  the population of the city and  $R$  its rank, using OLS method.  $P_1/P_2$ : primacy index;  $M$ : number of macrocephalic cities;  $P_{tot}$ : total urban population.

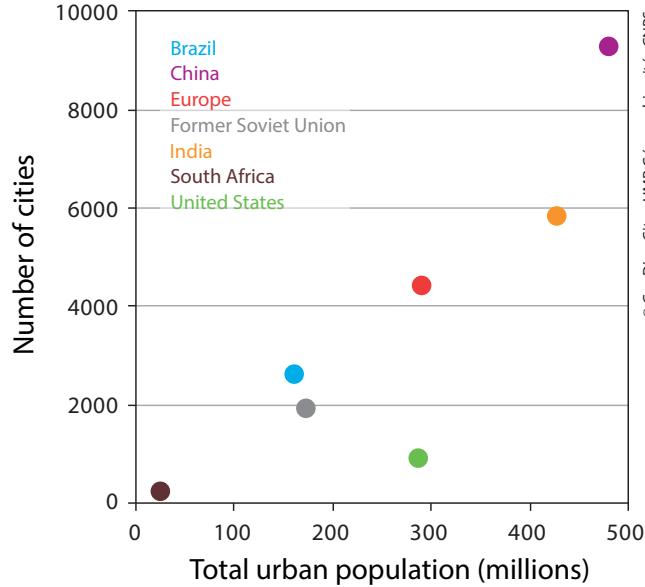


FIG. 2: Total urban population and number of cities per country.

Moscow is three times the size of St Petersburg (see Table II) while all the others except China are characterised by macrocephaly comprising two to four cities that are clearly discontinuous with the rest of the distribution. Thus in India, the three cities of Delhi, Mumbai and Kolkata, with around 16 million inhabitants each, stand out from the other cities in India, as do Durban, Cape-town and Johannesburg agglomeration in South Africa, while in Brazil the discontinuity is less marked, with São Paulo (20 million inhabitants) and Rio de Janeiro (12 million) some way ahead of Belo Horizonte with just over 5 million.

The largest cities are remarkable by their size, which obviously depends on the mass of the urban population in the country (see Figure 2), but this top part of the urban hierarchy is not sufficient to characterise the degree of concentration of an urban population, and it is relevant to look at the other parts of the distribution. Thus China, which ranks first for its mass, with a total urban population of around 500 million inhabitants,

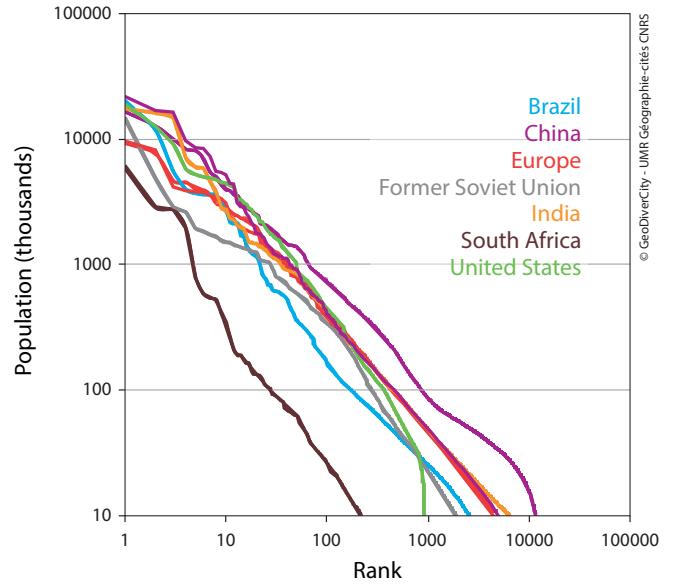


FIG. 3: City size distributions in seven countries around 2010.

also ranks first for the number of cities of over a million inhabitants, 66 in all. In contrast, India, ranking second for the weight of its total urban population (around 400 million) ranks only 4th for the number of cities with more than a million inhabitants – with 44 of these, it is outranked by the USA which has 51 for an urban population of only 287 million, which is therefore much more concentrated spatially. In contrast again, Europe where the urban population is more or less the same than in the USA (291 million) has only 39 cities of over a million inhabitants, and the degree of concentration is fairly similar to that of the former Soviet Union (173.5 million city-dwellers and 28 cities of over a million), or Brazil (161 and 23 respectively). While Europe remains the continent of small to medium cities and towns, and while India still has many small cities, the urban processes underway in India suggest that many of these cities are set to expand in the coming decades [28], and in China, although population concentration is still moderate, the massive size of the country and the closeness of certain

cities one to the other suggests that several large conurbations or megalopolises are likely to develop with 30 to 40 million inhabitants each, around the Pearl River Delta, in the regions round Shanghai, or between Beijing and Tianjin.

### **Urban hierarchies and urban growth at micro-level: testing Gibrat's model**

The universal shape of urban hierarchies that can be summarized by Zipf's rank-size rule as above or by a lognormal statistical distribution is explained as a first approximation by a stochastic repartition of the growth rates of individual cities in an urban system [21, 24]. Gibrat's law [14] predicts the statistical form of urban hierarchies and their persistence over time. This model assumes that cities grow in a manner that is proportional to their size. It is a growth model of the exponential type, but with growth rates (or relative population variations) that vary in the course of time. According to this model, despite considerable fluctuations in growth rates from one city to another over short time spans, long-term growth averages out at the same level for all cities in a given system.

We tested the hypotheses of Gibrat's law for the intervals between these two dates for which city population data is known in our bases. The hypothesis for generating a lognormal distribution stipulates that the variations in growth rate at each time interval do not depend on city size, and are distributed randomly from one period to another. Overall, the process observed in the BRICS complies with the model, which thus, at least in first approximation, remains a relevant reference for analysing the process of growth distribution in the city systems.

Everywhere, the correlation between city size and growth is low or absent. In South Africa, in India and China, whether at national level or for the main regions, the hypotheses of the Gibrat model are verified, and from the start of the 20th century [28, 29]. There is a discrepancy with the model, particularly in periods of vigorous growth, for the USA throughout the 19th century and in Europe after 1950, where there is a positive temporal autocorrelation of the growth rates. In Russia the process also appears in the course of the second phase of industrialisation in the 1930s and in the two decades during which there was a trend towards metropolisation of the largest cities and a cumulative decline of certain specialised cities [9]. We have demonstrated in a previous paper [13] how such deviations from a purely stochastic growth model could be explained by integrating in an urban growth model the interaction processes that convey innovation waves in the urban hierarchies. A consequence is that inequalities in city sizes are growing faster in real urban systems than according to a pure Gibrat's rule.

To conclude, the urban hierarchies and growth processes in a variety of large urban systems all over the world, including the BRICS countries, share generic com-

mon features despite major differences in their history as well as territorial and political organization. That is why Zipf's law and Gibrat's model albeit purely statistical models remain rather good standard references enabling international comparisons for a synthetic description of empirical urban hierarchies and urban growth processes, even though they do not directly provide an explanation for the underlying generative geographical processes (we suggest further theoretical complementary investigations in this direction, for instance by developing the family of Simpop models, [10, 22]). This conclusion is consolidated by the consistency of deviations from the models that can be rather easily related to different families of the historical development of urban settlements and politico-administrative organisation of the territories they belong to.

### **Macro and micro-dynamics: urban transitions and cities trajectories**

As we have seen before, understanding city size distribution and moreover urban growth processes cannot be done without referring to the history of each urban system and at least, even in a parsimonious abstract approach, to its stage in the seemingly universal urban transition. This process named by W. Zelinsky [31] using an analogy with the demographic transition describes the universal change from a dispersed and homogeneous spatial repartition of population in rural habitat towards much more concentrated diversified and hierarchized forms in urban settlements. The process which generally accompanies economic development started roughly at the beginning of 19th century in first industrialized countries and around 1950 in the less developed ones.

### **Macro-level trajectories of urban systems**

Different stages in urban transition clearly appear already from the condensed information in Table III where countries that experimented earlier urban transitions (Europe, Former Soviet Union, USA, Brazil) have much lower average urban growth rates during the last forty years than countries that are still in the exponential stage of the growing curve of their urbanization rate.

China appears clearly as the country in which recent urban development is the most rapid, with an average urban population growth rate of over 5% per year over 40 years. The Indian urban growth rate is half of this, but nevertheless vigorous during the period, with an average rate of 2% per year, while South Africa, with 3.2%, still reflects the fast urban growth rates across the African continent. In the USA and in Brazil growth is still over 1%, while in Europe and Russia it is just 1% or much lower.

These trends are partly determined by the stage

Country	Average growth rate (%/year)	Period
Brazil	1.11	1960-2010
China	5.20	1964-2000
India	2.10	1961-2001
Former Soviet Union	0.78	1959-2010
South Africa	3.15	1960-2001
Europe	1.01	1960-2010
USA	1.52	1960-2010

TABLE III: Average annual growth rates of population for cities of over 10.000 inhabitants during second half of the 20th century.

reached by the different countries in the urban transition, but they are also influenced by their particular history of urbanisation: in China political action, in particular that affecting migrations, for a long time put brakes on the explosion of urbanisation [7, 17], far more markedly than in India where it was rather social and family ties that slowed migration from rural areas [3, 23]. South Africa has remained at an average level among African countries since the end of Apartheid, on the one hand because of internal migrations from the former Bantustans, and on the other because of its attractiveness towards foreign migrants [11, 29]. Brazil and the USA being among the "new" countries in terms of waves of settlement had a former urbanisation rate systematically higher than in "old world" countries in Europe and Asia [25]. The slowing in urban growth rates has been more marked in Russia since the 1990s, as a result of decreases in the total population, especially in the Northern parts of the territory resulting from the dismantling of the Soviet Union [12, 16]. It has even been negative on average over the last two censuses (since 1989).

As a result, the weights of urban population of these countries in the total urban population of the world have been relatively increasing as shown in Figure 4 that compares their evolution over almost half a century.

These contrasted evolutions explain the very rapid turnover in rankings among the mega-cities (above 10 millions inhabitants), which are always the subject of controversy because the delineations chosen to measure these large urban areas have a considerable impact on their rank[35]. We can consider here the subset of these seven large countries included in the harmonised database to demonstrate the upheavals caused by unequal demographic growth over the last four decades. In the 1960s, the three largest cities by size were located outside the BRICS, with populations of 10.6 million for New York, 8.9 for Greater London, and 7.2 for Paris. These were followed on by Moscow (7.2), Shanghai (6.4), Delhi (5.9), Los Angeles (6), Kolkata (5.3), Mumbai (4.9), Beijing (4), Sao Paulo (with 3.8 having just overtaken Rio at 3.3) and Guanzhou (2). By the end of 20th century, this ranking had been completely overturned, with Sao Paulo joining or overtaking New York with some 20 million inhabitants, and 4 cities in the BRICS taking top places among the others: Delhi (17 million), Shanghai (16), Kolkata (16), Mumbai (15), Moscow (14), Beijing

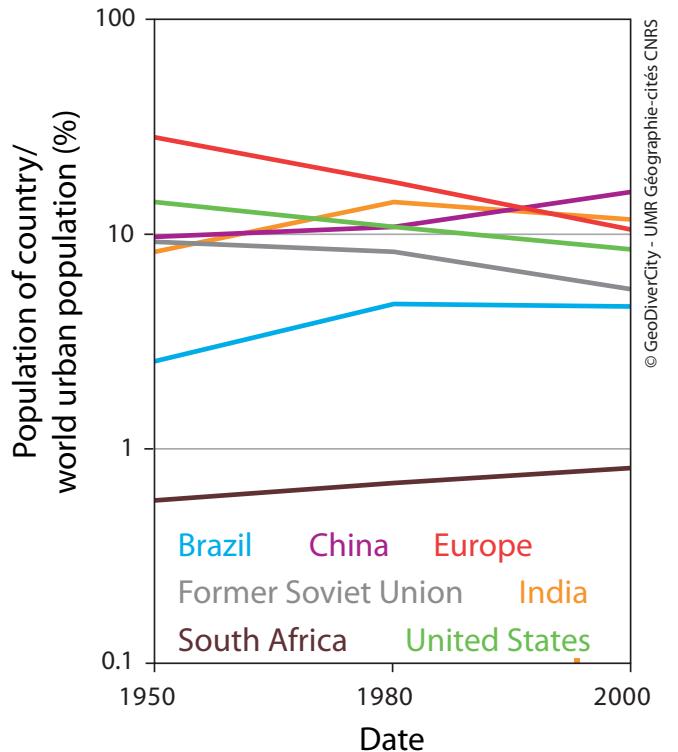


FIG. 4: Comparing the evolution of countries share of world urban population (%).

(14), and Rio (12). The European cities do not exceed 10 million, and they are joined in this megapolis group by Guanzhou, Shenzhen, and probably a few other Chinese cities if the migrant populations with more or less illegal status are taken into account.

#### Differentiating urban trajectories at micro-level

Too often however in urban studies the focus is only directed on these few "global cities" or "world cities" whose size and expansion is linked with the development of long distance exchange networks but not necessarily reflect other possible types of urban dynamics. We think necessary to develop knowledge about perhaps less prestigious names in urban hierarchies that nevertheless pro-

vide ways of living for a majority of populations and also participate in a decisive manner to the maintenance and renewal of urban systems.

To differentiate city trajectories in each country we developed a method that compares population evolution profiles by way of a correspondence factor analysis and a hierarchical ascending classification using the  $\chi^2$  distance (see Appendix 1). The implicit reference model is therefore that of proportional distributed growth proposed by Gibrat [14], and the trajectories show the most systematic discrepancies in relation to mean growth trend. The types of profile derived from the classification are shown on the left-hand graph (see Figures 5, 6, 7, 8, and 9) by the trajectory of the mean population for each type, and to the right for a trajectory showing the relative evolution of the mean weight of this type of city in the urban system under consideration (semi-logarithmic graphs enabling on the one hand a comparison of growth intensities represented by the slopes, and on the other immediate visualisation of any differences in evolution (they are fairly frequent) associated with positions in the urban hierarchy).

Naturally, the shape of city trajectories in relation to that of the system to which they belong can vary with the period considered. We chose the period 1960-2010 for reasons of comparability between countries, and also to restrict the number of major historical turning points which if too numerous would make it more difficult to efficiently anticipate possible evolutions in the 21st century. By construction, these classifications show classes of cities where the "absolute" evolutions are often all increasing (rarely including an inflection), but grouped according to their relative growth, which may be faster or slower than that of the country as a whole. To compare the degree of heterogeneity of these trajectories across countries, we measured the share of variance remaining between classes. The order of the countries remains the same, whether the partition is into two, three or five classes. In the case of five classes, the Former Soviet Union shows the greatest diversity in trajectories (76% interclass variance) while in Brazil the trajectories appear less differentiated (63%), the other countries falling between these two (70-73%).

Depending on the form of the classification tree, there are two clearly distinct types of trajectory in China, while three families of trajectory can be observed in the other countries. To obtain more detail, and in relation to levels of heterogeneity, for mapping purposes (Figures 5,6, 7, 8, 9) we retained four classes of city for China (Figure 8), India (Figure 7), South Africa (Figure 9) and the former Soviet Union (Figure 6), and five for Brazil (Figure 5). The classes can be grouped according to the orientation of their trajectories in relation to the city system to which they belong, generally in two types, "winners" and "losers", but a stable type also appears in India, China, the former Soviet Union and South Africa. These cities that maintain their relative weight in the system are often long-standing cities with administrative func-

tions – certain State capitals in India, provincial capitals in China regional capitals in Russia, and medium-sized cities in South Africa.

In Brazil (Figure 5) almost all the large metropolitan areas, which are the capitals of the federal States, have strongly ascending trajectories. The recent dynamic thus has the effect of accentuating the hierarchical inequalities in the country. India too exhibits this process of reinforcement at the top of the urban hierarchy, with three quarters of the largest cities exhibiting ascending or stable trajectories. In contrast, in the other countries, what can be seen is a form of "catching up" by the smaller cities and peripheral areas. The markedly ascending trajectories tend to be characteristic of a few smaller cities, often in the vicinity of the large metropolises, in India (Figure 7) or South Africa (Figure 9). In the former Soviet Union (Figure 6), it is most of the cities located on the peripheries of Russia to the South (Central Asia, Azerbaijan) and West (Ukraine, Belarus), and some Russian cities near deposits of mineral resources, that gain weight relative to the others. In China (Figure 8), two processes are seen, where the large cities in the East (Shenzhen, Xiamen) are gaining weight in the system while medium-sized cities in Xinjian province and Inner Mongolia are developing fast, illustrating the catching-up by peripheral regions.

There is a long-term trend in most city systems whereby it is mostly the small urban entities that show relative decline. Indeed, all other things being equal, the smaller cities are more likely to be distant from the main waves of innovation, or else to be highly specialised in declining sectors of activity, so that they lose their influence on local markets as a result of acceleration in the speed and capacity of transport systems. The only exception appears in China (see Figure 8) where classes of cities with an ascending profile are made up mainly of small cities, a third of which in Special Economic Zones in which innovating activities have been set up and to which populations migrate. The classic process of hierarchical diffusion of innovation is partially disconnected here from the previous structure of the city system. However cities with a "winning" trajectory are mainly located in the immediate vicinity (roughly less than 200 km) of large metropolitan areas, for instance Guangzhou or Shanghai. The importance of policy in urban dynamics can thus be seen in the creation of new cities, at the same time preserving a degree of spatial and historical coherence with the earlier trends in the city system. In a territory where urbanisation is long-standing, like China, these new urban developments fit themselves into the previous urban spatial pattern, while in "new" countries like Brazil, the USA and South Africa, and also the Eastern part of the Russian Empire, urban creations ran alongside the settlement of new territories.

## Conclusion

When dealing with complex systems, it is important to relate the configurations of urban hierarchies observed on macro-geographical scale of States to the trajectories of the urban entities they comprise on micro-geographical level. This paper thus demonstrates the usefulness of constructing a harmonised database enabling the description of the evolution of urban entities and their spatial extension over time.

We provide for the first time a comparable overview of the systems of cities in the five BRICS countries. Using Zipf's distribution of city sizes and Gibrat's urban growth models as benchmarks for the comparison, we have demonstrated that the dynamic urban processes in BRICS during the last fifty years were rather similar to those observed for instance in Europe or the United States. There is nothing resembling a specific urban dynamic in BRICS whether we consider the shape of urban hierarchies, city size distribution, or distribution of urban growth among individual cities.

Of course differences do exist, but they relate to the specific developmental pathway of these countries, including the relative delay in the urban transition compared to more developed countries, which explains their very high mean urban growth rates – the case of Russia being excepted. History matters too for differentiating the evolution of urbanisation rates, which registered higher values earlier in Russia and Brazil compared to South Africa, China and India.

When shifting from the macro-scale of countries to the micro-scale of individual cities, the most striking fact is the diversity of urban trajectories that exhibit contrasted patterns of booming growth or relative decline everywhere. Moreover, these qualitatively divergent local

evolutions are disseminated in all parts of each territory with few remarkable spatial concentrations.

## Appendice 1. TrajPop software (author:Robin Cura)

These analyses are performed using the TrajPop script, developed in the ERC GeoDiverCity project. This tool, based on the free statistical environment R, performs a Correspondence Analysis on a temporal population table. The coordinates of cities on the orthogonal components then make it possible, after re-entering the weights of the cities, to generate a matrix for population discrepancies among cities (measured using a  $\chi^2$  distance); to this matrix is applied a Hierarchical Cluster Analysis (using the Ward method, which tends to minimise intra-class variance and to maximise inter-class variance). From the tree generated by this clustering, the number of clusters is chosen so that it sufficiently distinguishes the trajectories while at the same time enables them to be mapped. It is then possible to analyse trajectory classes using the TrajPop graphic and numerical print-outs, for instance by studying the evolution of the relative weights of the classes in the system in the course of time (<http://trajpop.parisgeo.cnrs.fr>).

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[33] We would like to acknowledge the assistance of Hélène Mathian in the conception of the data models.

[34] Island Areas, Alaska and Porto Rico excluded

[35] See for instance the classifications given on websites <http://citypopulation.de>, <http://population.data.net>, or those provided by the United Nations (<http://esa.un.org/unup>).

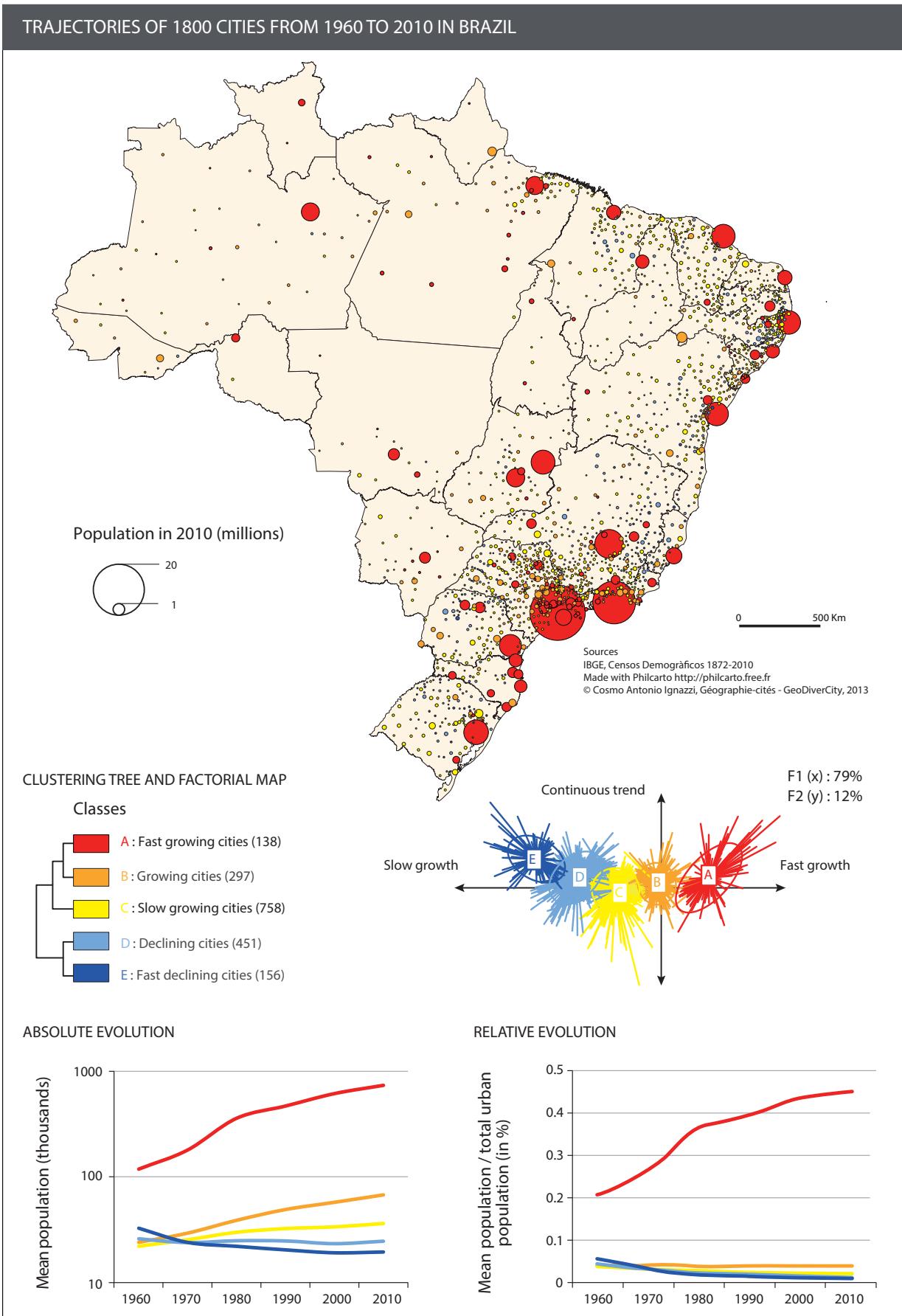


FIG. 5: Urban trajectories in Brazil.

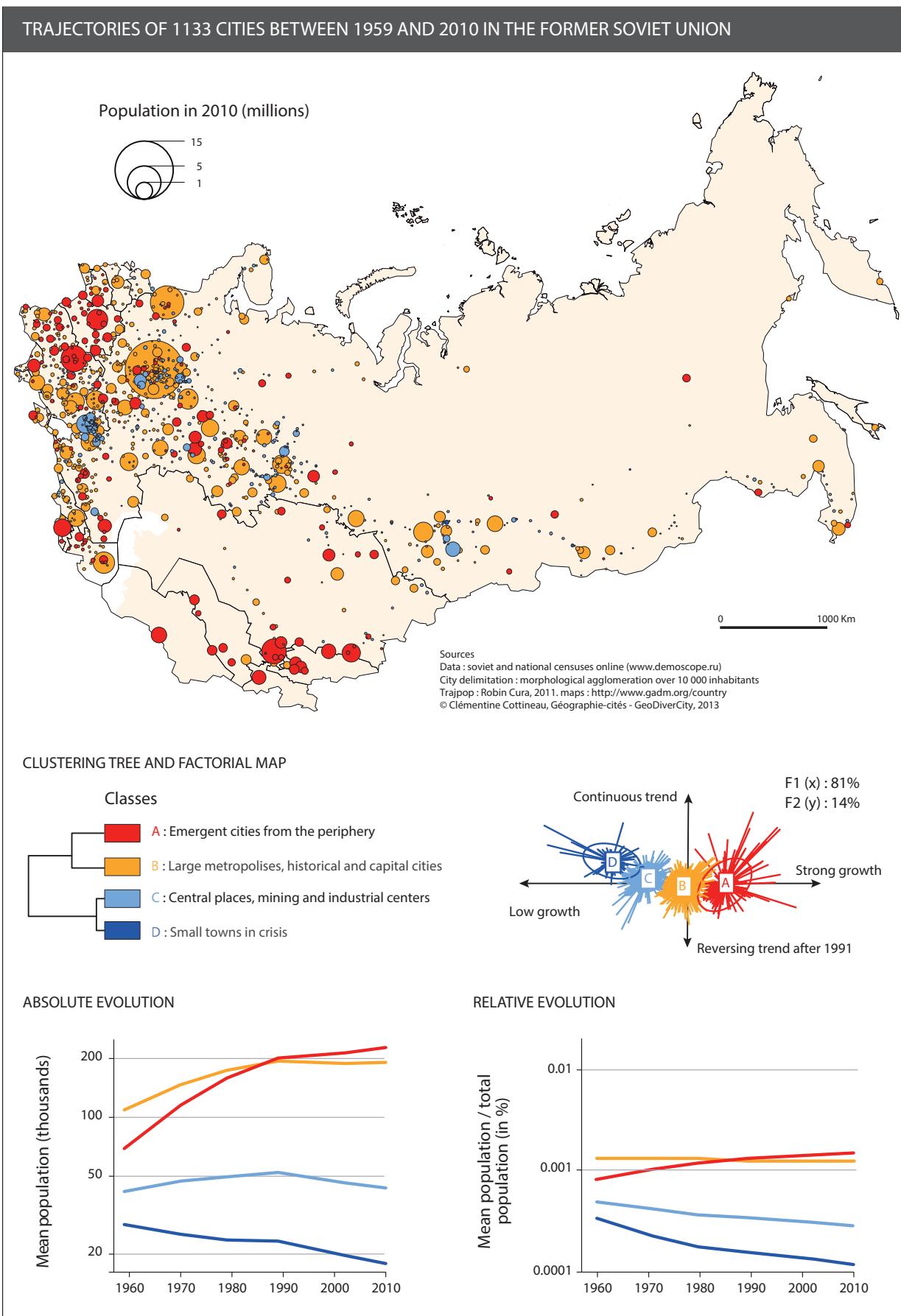


FIG. 6: Urban trajectories in former Soviet Union.

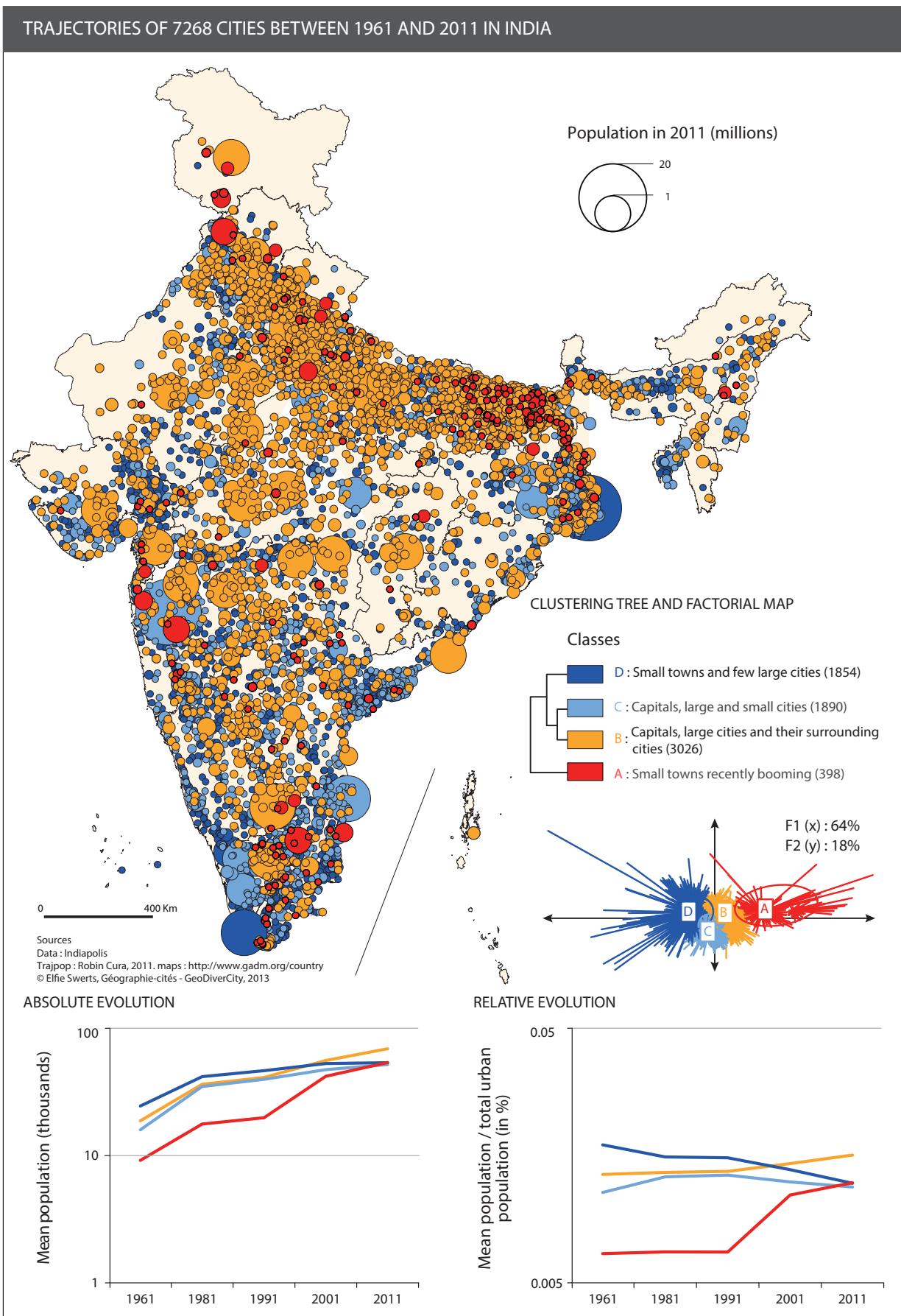


FIG. 7: Urban trajectories in India.

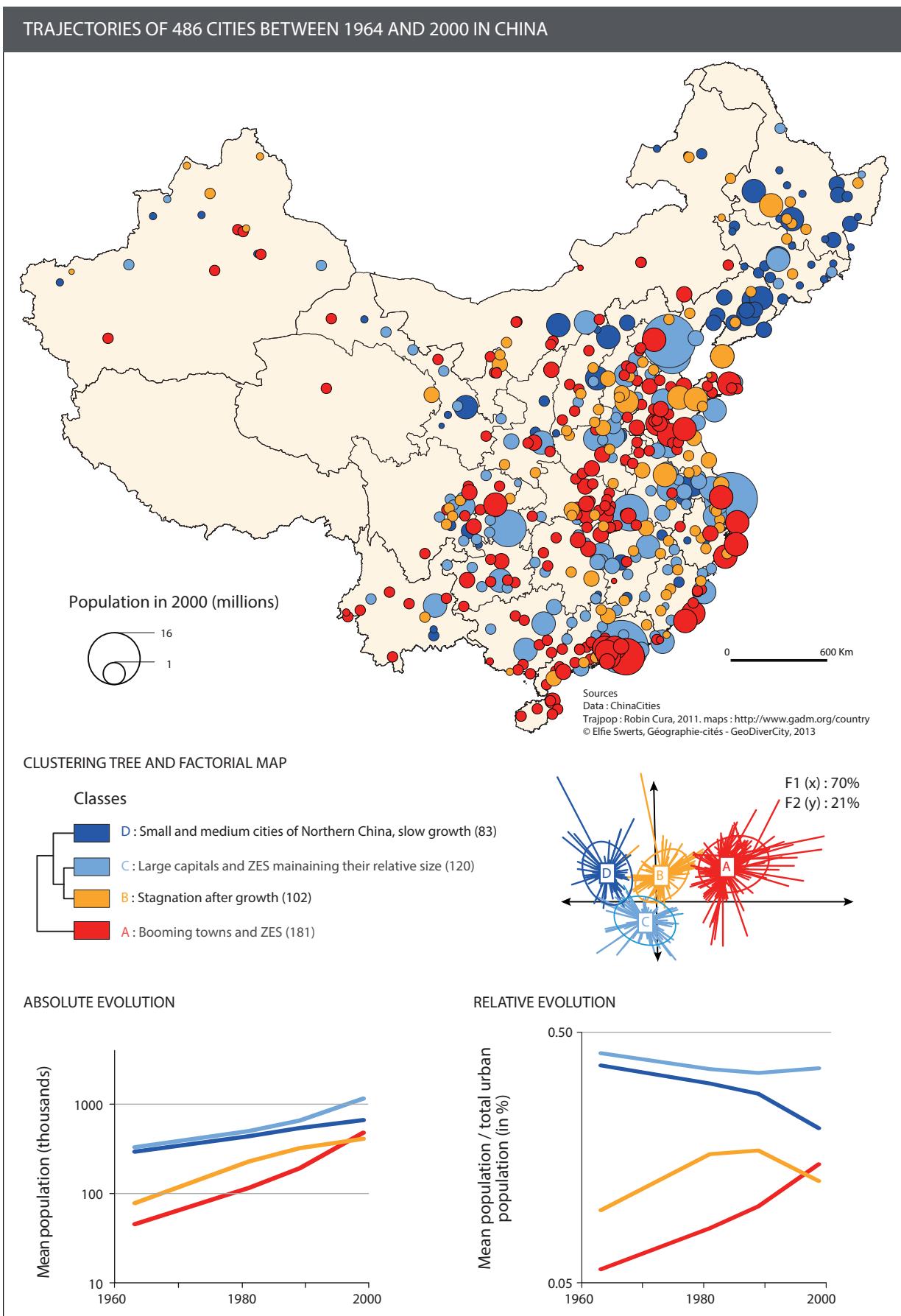


FIG. 8: Urban trajectories in China.

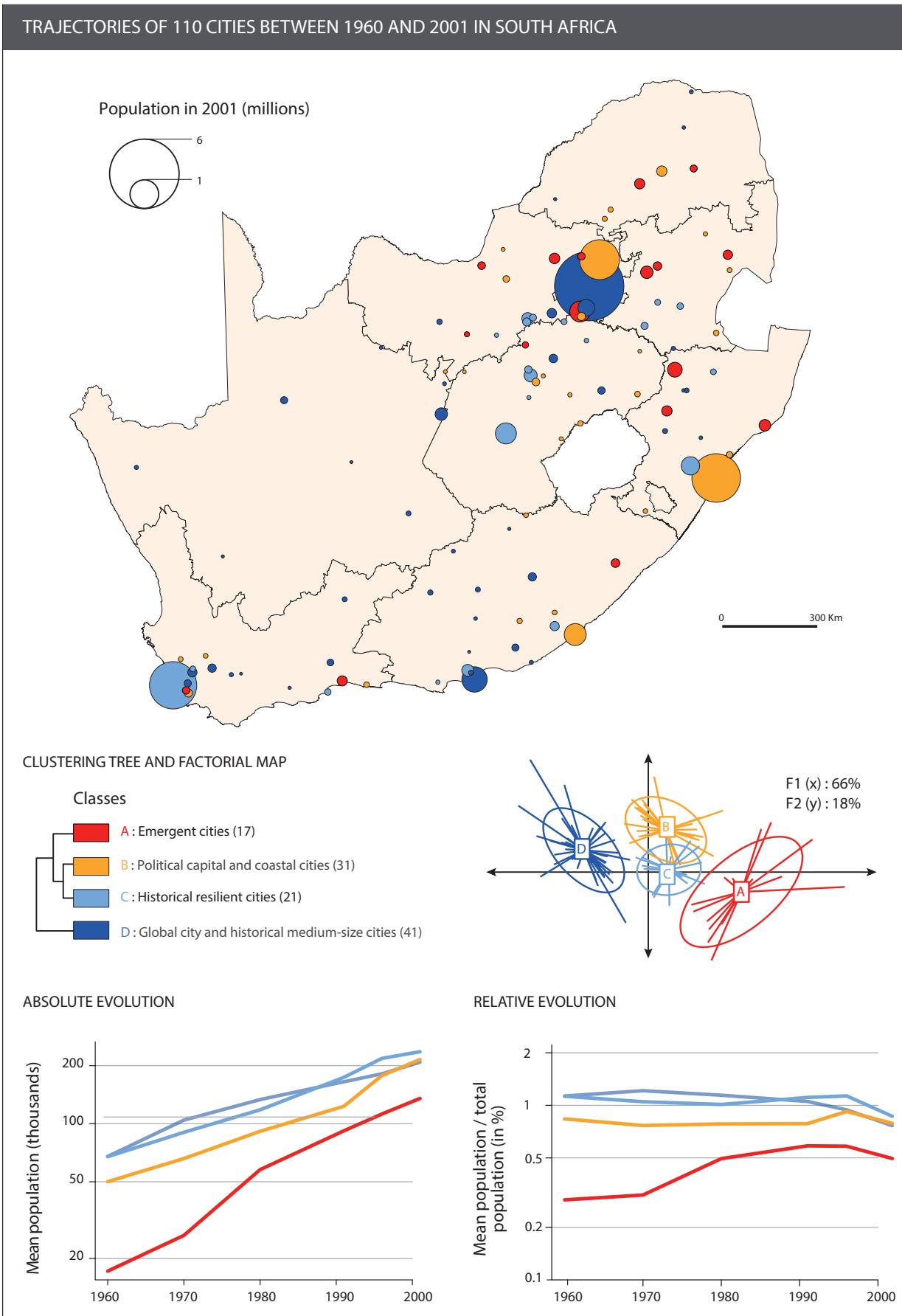


FIG. 9: Urban trajectories in South Africa.